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Mechanics of the Connecting Rod

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THE MECHANICS OF THE CONNECTING ROD

BY

JACOB H. WALLACE

THESIS FOR THE DEGREE OF BACHELOR OF SCIENCE
IN MECHANICAL ENGINEERING

IN THE
COLLEGE OF ENGINEERING
OF THE
UNIVERSITY OF ILLINOIS
PRESENTED JUNE, 1903

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

JACOB H WALLACE

ENTITLED THE MECHANICS OF THE CONNECTING ROD

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering.

L. P. Breckenridge

HEAD OF DEPARTMENT OF Mechanical Engineering.

31567

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THE MECHANICS OF THE CONNECTING ROD.

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I. Kinematics of the Connecting Rod.

a. Nature of the Motion of the Rod.

A connecting rod as it performs its ordinary functions, has its motion so constrained that one end moves in a circle while the other end reciprocates in a straight line. In a motion of this character is combined the two simple motions of translation and a rotation ---a translation along the line of stroke and a rotation about the wrist pin center.

Ordinarily the crank has a uniform angular velocity about the shaft center. Under this condition the crank pin center has a simple harmonic motion in any given direction. If the length of the rod were infinite, the motion of the wrist pin center would be a simple harmonic reciprocation. Since the length of the rod is finite, the motion of the wrist pin center is not harmonic but varies with the ratio of the length of the rod to that of the crank.

b. Velocities of Points on the Rod.

Let ω denote the angular velocity of the crank and n the number of revolutions per minute;

Then $$\omega = \frac{2\pi n}{60}$$

Also let v denote the tangential velocity of the crank pin center, and r the length of the crank arm;

Then $$v = r\omega = \frac{2\pi rn}{60}$$

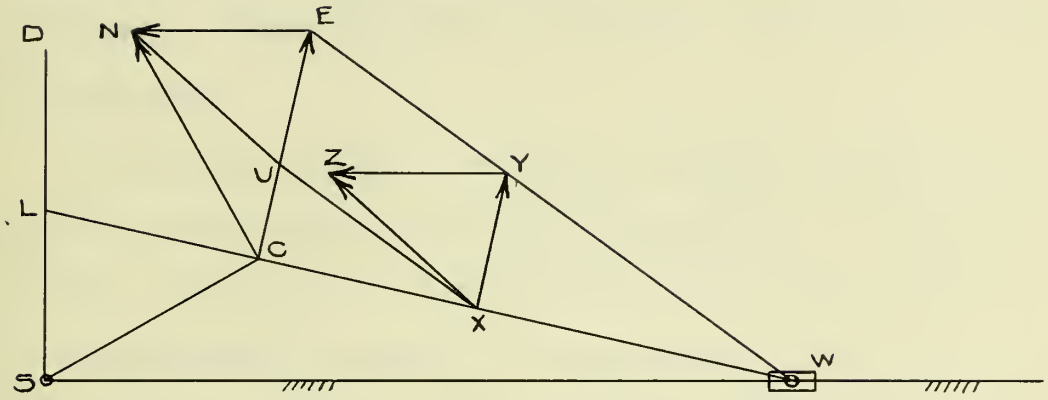

Fig.1.

In Fig. 1, let CN perpendicular to SC, represent, to some scale, the tangential velocity of C. Since the velocity of C relative to W must be perpendicular to the rod, and the entire rod has a translation parallel to the line of the stroke, the velocity of C is made up of two components, one of which, CE, is perpendicular to CW, and the other, EN, is parallel to WS.

In order to find the velocity of any point X on the rod, join E and W, and through X draw XY perpendicular to CW until it intersects EW in Y. Then XY represents the velocity of X relative to W. This follows from the principle that the velocity of a point on a rotating system is proportional to the length of the line joining the point and the center of rotation. Since every point on the rod has the same velocity of translation, draw YZ equal and parallel to EN, join X and Z. Then XZ, the resultant of XY and YZ, is the actual velocity of the point X.

Draw XU parallel to EW until it intersects CE in U, and join

U and N. Then in the triangles XYZ and UEN, the sides XY and YZ are equal and parallel to UE and EN respectively. Hence the triangles are equal, and UN represents the velocity of the point X. This construction furnishes a simple method for determining the velocity of any point on the rod.

Let SD, perpendicular to SW, meet WC, produced, in L. Then in the triangles CEN and CLS, CE, EN, and CE are perpendicular to CL, LS, and SC respectively. Therefore the triangles are similar, and homologous sides represent corresponding velocities --- CS represents the actual velocity of C, CL the velocity of C relative to W, and LS the velocity of the translation of the rod. This construction furnishes a convenient method for finding the velocity of C relative to W.

c. Accelerations of Points on the Rod.

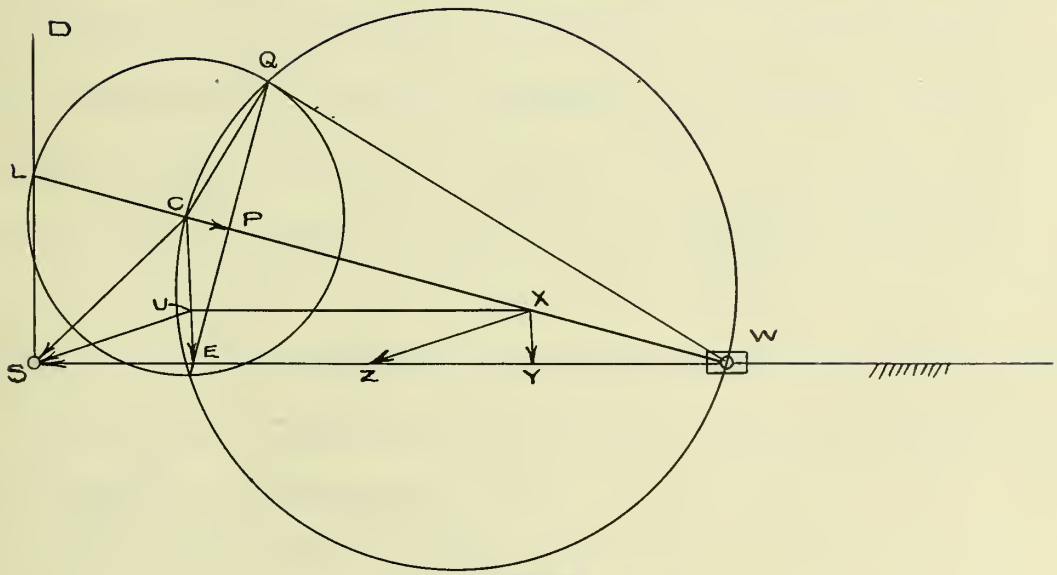

Fig. 2.

The rotation of the crank CS (Fig. 2) around the shaft center S. is assumed to have a uniform angular velocity. Under this condition, the crank pin center has the radial acceleration $\frac{-v^2}{r}$, directed towards the shaft center. If CS = r represents, in magnitude, v, the velocity of

C,r also represents the radial acceleration of C, but to some other scale.

Since the motion of the rod is a combination of translation and rotation, the acceleration of the crank pin center is made up of two components. One due to the translation is parallel to the line of stroke; the other due to the rotation of the rod about W is itself made up of two components, one radial, i.e. directed towards W, and the other tangential, i.e. perpendicular to CW.

Let α_1 denote the component of the acceleration of C directed towards W, v_1 the velocity of C relative to W, and r_1 the radius of the rotation.

Then $\alpha_1 = \frac{v_1^2}{r_1}$ or $\alpha_1 : v_1 = v_1 : r_1$

Consequently the velocity of C relative to W is a mean proportional between the radial acceleration of C directed towards W and the radius of rotation. In order to determine the vector representing the radial component, construct a circle with C as a center and CL as a radius, and also a second circle on CW as a diameter (See Fig. 2). The common chord QPF intersects CW at P, and SW at S. In the similar right triangles WQC and QPC, QC is a mean proportional between WC and CP. But CW is the radius of rotation of C relative to W, and QC=CL is the velocity of C relative to W.

Then $CP:CL = CL:CW = V_1:r_1 = \alpha_1:V_1$

And $CP:CL = \alpha_1:v_1$ or $\frac{CP}{CL} = \frac{\alpha_1}{v_1}$

But $CL = v_1$

Hence $CP = \alpha_1$

Consequently CP represents the radial component of the acceleration of

C relative to W.

Since the tangential acceleration of C relative to W is perpendicular to CW, the two components form the sides of a rectangle in which the actual acceleration of C relative to W is the diagonal. But since CP and QE are perpendicular to each other they coincide with two sides of the rectangle. Consequently the diagonal of the rectangle must connect C and some point on the line QE.

The acceleration of C, represented by CS, is made up of two components, one of which is parallel to the line of stroke and the other joins C and a point of the line QE. Hence draw CE, and the lines ES and CE represent the required components -- ES represents the acceleration of translation and CE that due to the rotation about W.

The acceleration of any point on the rod due to its rotation relative to W is evidently parallel to CE and proportional to the distance from W, and the acceleration of translation is the same for all points of the rod. Let X be any point on the rod and draw XY parallel to CE, meeting WS in Y: also lay off YZ equal to and parallel to ES and join X and Z. Then XZ, the resultant of XY and YZ, represents the acceleration of the point X.

Draw XU parallel to WS until it intersects CE in U, and connect U to S. Then in the triangles XYZ and UES, XY and YZ are parallel and equal respectively to UE and ES. Hence US is equal and parallel to XZ, and represents the acceleration of the point X. This construction furnishes a simple method for determining the acceleration of any point on the rod.

II Dynamics of the Connecting Rod.

a. System Equivalent to the Rod.

If a body free to move in a plane is acted upon by a force in such a way that the line of action does not pass through the mass center, the resistance with which the body opposes motion is made up of two parts one of which opposes a linear acceleration of the center of gravity and the other opposes an angular acceleration relative to the center of gravity. The first is expressed by the equation,

$$F = M\alpha$$

in which F, M and α denote respectively force of inertia, mass and acceleration. The resistance offered to rotation is equivalent to a couple and is expressed by the equation,

$$C = I\ddot{\theta}$$

In which C, I and $\ddot{\theta}$ denote respectively the moment of the couple, moment of inertia and angular acceleration. From these equations it is evident that dynamically a system may be replaced by an equivalent system having the same valued of M and I, and the same mass center.

Let the rod be replaced by a system composed of two masses concentrated at two points; and let m_1 and m_2 denote the two masses into which M is divided, distant respectively h_1 and h_2 from the mass center of the rod; further let k denote the radius of gyration of the rod about an axis through the mass center perpendicular to the plane of rotation. Then the three conditions stated above are expressed by the equations;

$$m_1 + m_2 = M$$

$$m_1 h_1 - m_2 h_2 = 0$$

$$m_1 h_1^2 + m_2 h_2^2 = I = Mk^2$$

The value of k may be determined experimentally by swinging the rod as a pendulum and making proper substitutions in the following formula:

$$k^2 = \frac{T^2 gh}{\pi^2} - h^2$$

in which T, g, and h denote respectively time of a single swing, acceleration due to gravity and distance of mass center from the point of support.

b. Resultant Inertia Force of the Rod.

Let CW, Fig. 8 represent a connecting rod in which G is the center of gravity and W and O are points in which the mass of the rod is considered concentrated. OO_1, GG_1 and WW_1 represent respectively the accelerations of O, G and W.

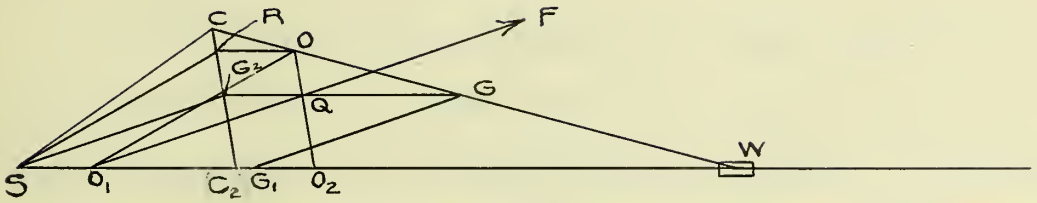

Fig. 8.

The line of action of the inertia force of the mass at O is in the direction of acceleration OO_1, and the line of action of the inertia force of the mass at W lies likewise in WS. Hence the intersection C_1 of OO_1 and WS is a point in line of action of the resultant

inertia force of the rod.

When the motion of the rod is considered as made up of translation of the mass center parallel to the line of stroke, and a rotation about the wrist pin center, the line of action of the inertia force due to the translation passes through G parallel to WS and that due to the rotation passes through O parallel to CC_2. The intersection Q of these two lines of action is a point on the line of action of the resultant inertia force of the rod. Therefore a line passing through Q and O_1 is the line of action of the resultant inertia force of the rod.

By construction GG_2, OR and WS are parallel to each other. GG_1 is parallel to G_2S, RS is parallel to OO_1 and OO_2 is parallel to CC_2. Then in the triangles RSG_2 and OO_1Q, OQ is parallel and equal to RG_2, OO_1 is parallel and equal to RS. Hence the triangles are equal and homologous sides are parallel O_1Q, SG_2 and G_1G are equal and parallel to each other. This construction furnishes a simple method of determining the line of action of the resultant inertia force of the rod.

In order to find the position for maximum component of the resultant inertia force at right angles to the rod, it is necessary to find only the position for a maximum component of the acceleration of the mass center perpendicular to the rod, for the inertia force is proportional to the acceleration of the mass center. In Fig. 4, let S be the center of the shaft, AEC the path of the crank pin center for a half revolution and DG_2G_3F a polar curve of the resultant inertia force and $DHSH_1E$ a polar curve of the component of SG_2 along

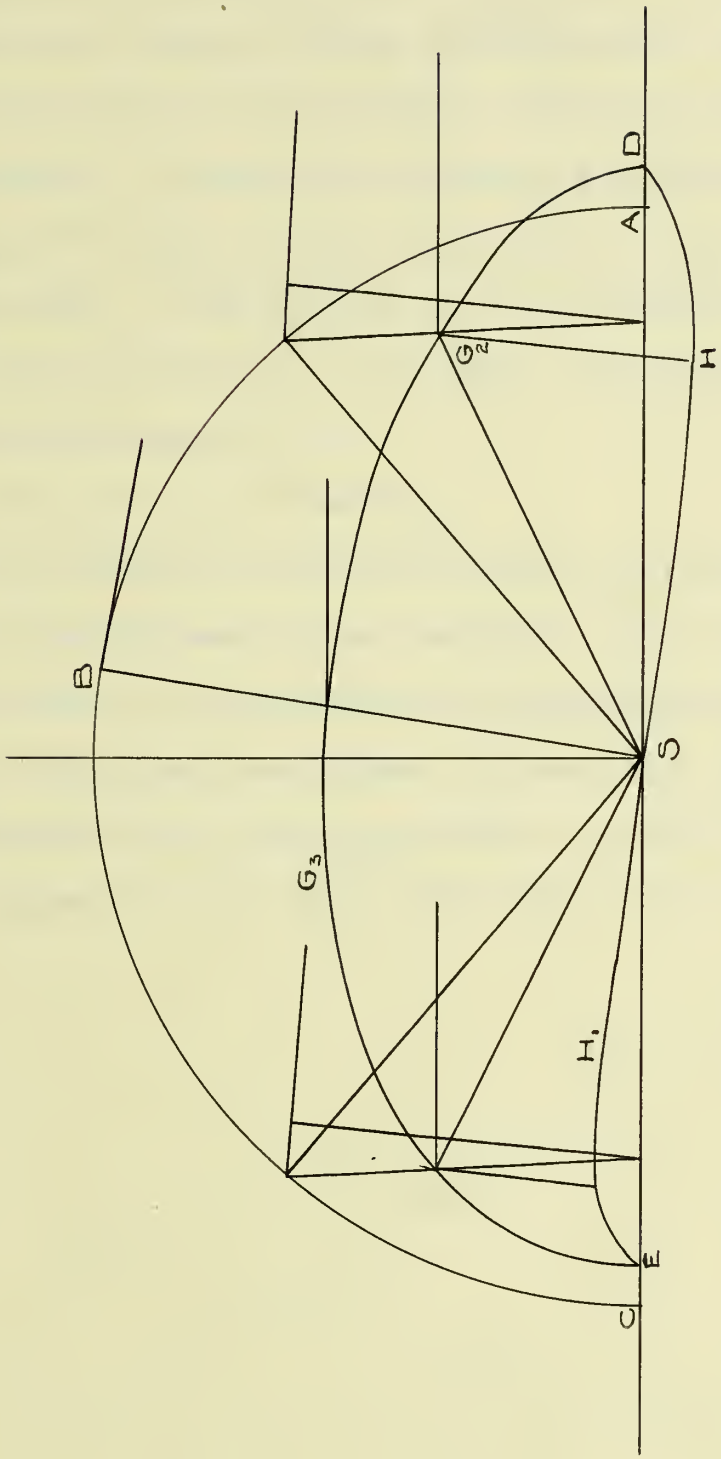

FIG. 4

the rod. Then intercepts properly taken between the curves DG_2G_2E and $DHSH_1F$ represent the components of of SG_2 at right angles to the rod. As willbe seen from the figure the position for HG_2 a maximum is not easily chosen, nor is the analytical method convenient in determining this position. However, the position of the rod in which it makes an angle of 90° with the crank has probably as great a value for HG_2 as any other. This position is not the position for the coincidence of SG_2 and HG_2, but in the usual ratios of crank to connecting rod is very near to it.

c. Reactions at the Bearings.

If the connecting rod is considered as a free body, its inertia force is equilibrated by two reactions - one at the wrist pin, and one at the crank pin. The reaction at the wrist pin is evidently at right angles to the cross head guides. Consequently, the reaction at the crank pin must be such a force as to form a resultant with the reaction of the wrist pin, equal to the total inertia force of the rod.

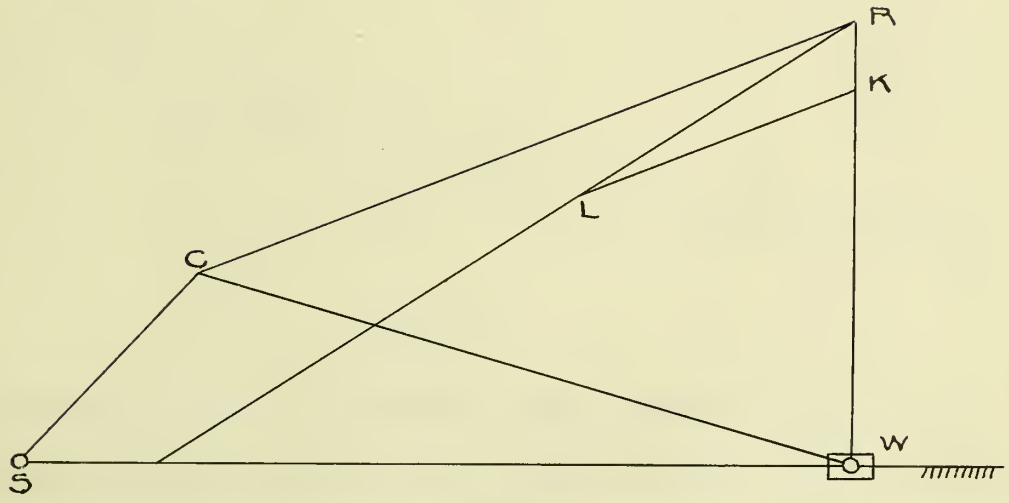

Fig. 5.

In Fig. 5 let LR represent the total inertia force of the

rod. RW is a perpendicular to SW, and CR merely joins the intersection of LR and WR with C. Then RW and CR represent the lines of action of the reactions at W and C. Draw through L a parallel to RC until it intersects WR at K. Then LR, RK and KL form a force polygon; and RK represents the reaction at W, and KL the reaction at C.

The reaction at the crank pin C, when the crank is considered as a free body, produces a turning movement or couple with the reaction at the shaft S. The reactions are consequently equal and act in the same direction and sense.

III Stresses in the Rod due to Inertia Forces.

a. Load Curve.

In order to determine the distribution of the loading throughout the length of the rod, let the rod be assumed in the position as shown by CW Fig.6.

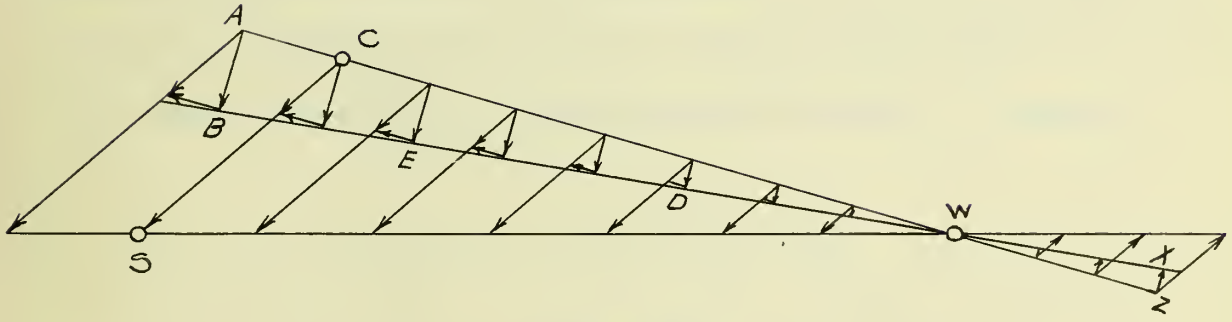

Fig.6.

and considered as made up of sections taken at right angles to the line CW. Then the inertia force of any section is the product of its mass and the acceleration of the point on the rod corresponding to the center of gravity of the section. The component at right angles to the

rod evidently produces an effect upon therod similar to that of a load of the same intensity. If the center line of the rod is taken as a base and the compoonents of the inertia forces at right angles to the rod, laid off throughout the rod, a curve ABEDWXZ will be formed which represents the loading throughout the rod. Since the rod is supported at only two points it may for any given position, be treated as a simple beam.

Since the acceleration of gravity is constant in magnitude and direction, the loading due to the weight of the rod is added to that due to the motion in one part of the revolution and is subtracted from it in another. For example in the horizontal engine the load is greater when the rod is below the line of stroke than when it is above it.

b. Shear Curve.

The shear curve is a first integral curve of the load curve. Then the area of the load diagram, up to any section is the ordinate, numerically, of the shear curve for that section. Due allowance must be made for the reactions at the points of support.

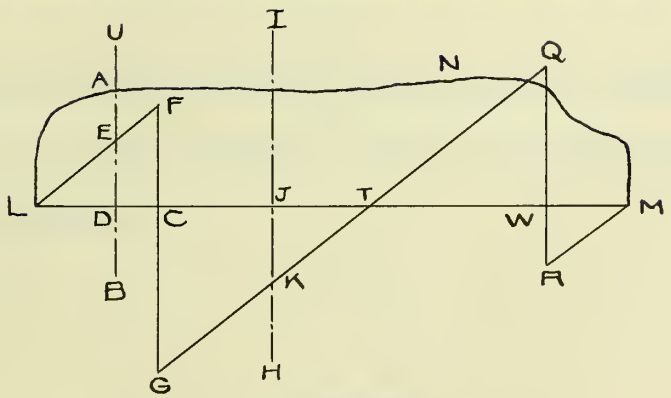

Fig. 7.

If LM, Fig. 7 represents a simple beam loaded as shown by the

curve LANM, the area DAL to the left of the section EU is represented by DE. When the point of support C is passed, the reaction, acting in the opposite sense to the load, is considered negative and added to the ordinate representing area. JK represents this sum for the section IH. A break in the shear curve evidently occurs at the reactions. Since the sum of the reactions equals the load, the shear curve closes at M, and the area (LFC + TQW) is equal to the area (CQT + WRM). This fact furnishes a check on the distribution of the load and the value of the reactions.

c. Bending Moment Curve.

The bending moment curve bears the same relation to the shear diagram that the shear curve bears to the load diagram: hence the bending moment curve may be obtained by the method previously described for finding the shear curve.

d. Stresses Due to Shear and Bending Moment.

The ordinates of the shear and bending moment curves measure directly the shear in the units chosen. If S denotes the shear of a section, A the area, and s the shear per unit area,

$$s = \frac{S}{A}$$

If M denotes the bending moment, I the moment of inertia of the section, c the distance from the neutral axis to the remotest fiber, and s_1 the stress due to bending,

$$s_1 = \frac{Mc}{I}$$

IV. Investigation of Particular Rods.

a. "Zimmerman and Sayers" Rod.

Fig. 8 shows a connecting rod designed by Zimmerman and Sayers of the class of 1897. The engine is a 60 HP tandem compound high speed steam engine designed to run at a speed of 260 R.P.M. The leading dimensions are: cylinders, 8 and 14 by 12 inches; length of crank 6 inches; length of connecting rod 26 inches; steam pressure 150 lb. gauge. The value of M was found by weighing. The center of gravity was located by balancing on a knife edge. The time T was observed by means of a stop watch. The value of g taken was that determined by Prof. Sager of the Department of Physics, University of Illinois. The value of k was calculated. The rod was considered as composed of two masses, one at W and the other at O. The value of h_2 was calculated. The value of v was obtained by means of the formula;

$$v = \frac{2\pi rn}{60}$$

in which n denotes the R.P.M. The value of α_c was obtained by means of the formula:

$$\alpha_c = \frac{v^2}{r}$$

By the graphical method α_G was determined. The resultant inertia force F_1 was obtained by means of the formula:

$$F = M\alpha_G$$

The inertia force F_2 due to the weight of the rod was obtained by means of the formula:

$$F_2 = Mg \cos\phi$$

in which ϕ denotes the angle made by the rod and a horizontal line.

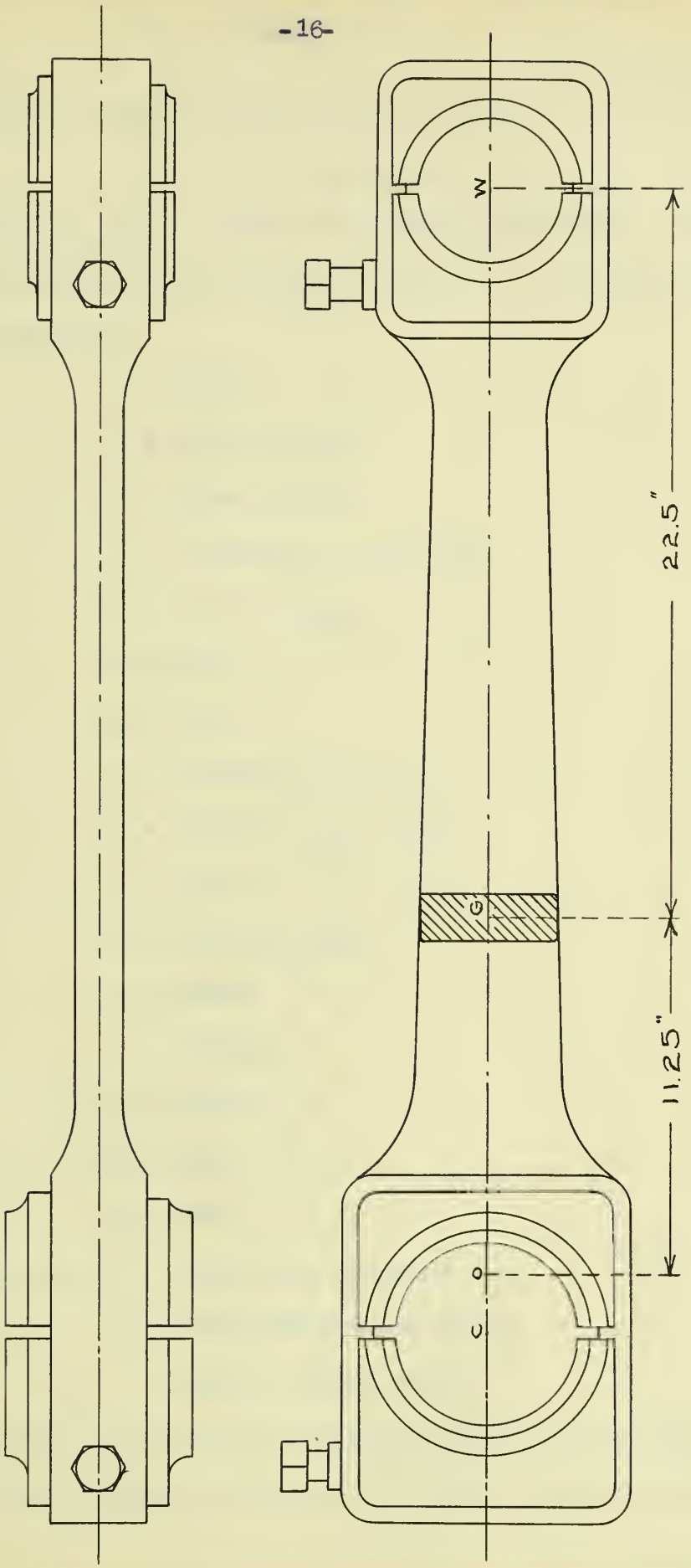

FIG. 8

The total inertia force F is the sum of F_1 and F_2.

$$F = F_1 + F_2$$

The reactions R_c, R_s and R_w were determined graphically. The value of s_1 was calculated from the formula $s = \frac{Mc}{I}$. The following are the results obtained:

M = 190 lb.

h = 24.625 inches.

T = 0.945 seconds

g = 32.17092 ft. per sec.^{2}

k = 15.845 inches.

h_1 = 22.81 "

h_2 = 11.25 "

v = 13.619 ft.per sec.

α_c = 370.573 ft.per sec.^{2}

α_G = 202.91 " " "

F_1 = 38552.9 poundals

F_2 = 6026.9 "

F = 44579.8 "

R_c = 24420 "

R_s = 24420 "

R_w = 20455 "

Maximum moment at F_2 = 14580 inch poundals

s_1 = 3850 poundals per sq.in.

= 119.05 lb.per sq.in.

In the investigation of stresses, the rod was assumed to make angle of 90° with the crank as shown in Fig.9. The curve ABDEFWHZ

shows the distribution of the load due to the motion: the curve AB'D'F'H'Z shows that due to the weight of the rod. The curve $AB_1D_1C_1E_1I_1J_1WZ$ is the shear curve. The curve $AB_2D_2E_2F_2WZ$ is the bending moment curve the maximum occurring at F_2.

In Fig.10 the curve DG_2G_2E is a polar curve of the resultant inertia force of the rod. The line of action of the resultant inertia force passes through a region indicated by P, for all positions of the rod. The curve DH_2J_2E is a polar curve for the reactions of both the crank pin and shaft. The vertical intercepts between the curves DG_2G_2E and DH_2J_2E represent reactions upon the crosshead guides. The curve $DHSH_1E$ is a polar curve of the component of resultant inertia force along the rod. Intercepts properly taken between the curves DG_2G_2E and $DHSH_1E$ represent the components of the resultant inertia force at right angles to the rod.

Volumes and weights of the "Zimmerman and Sayers" Rod throughout its length.

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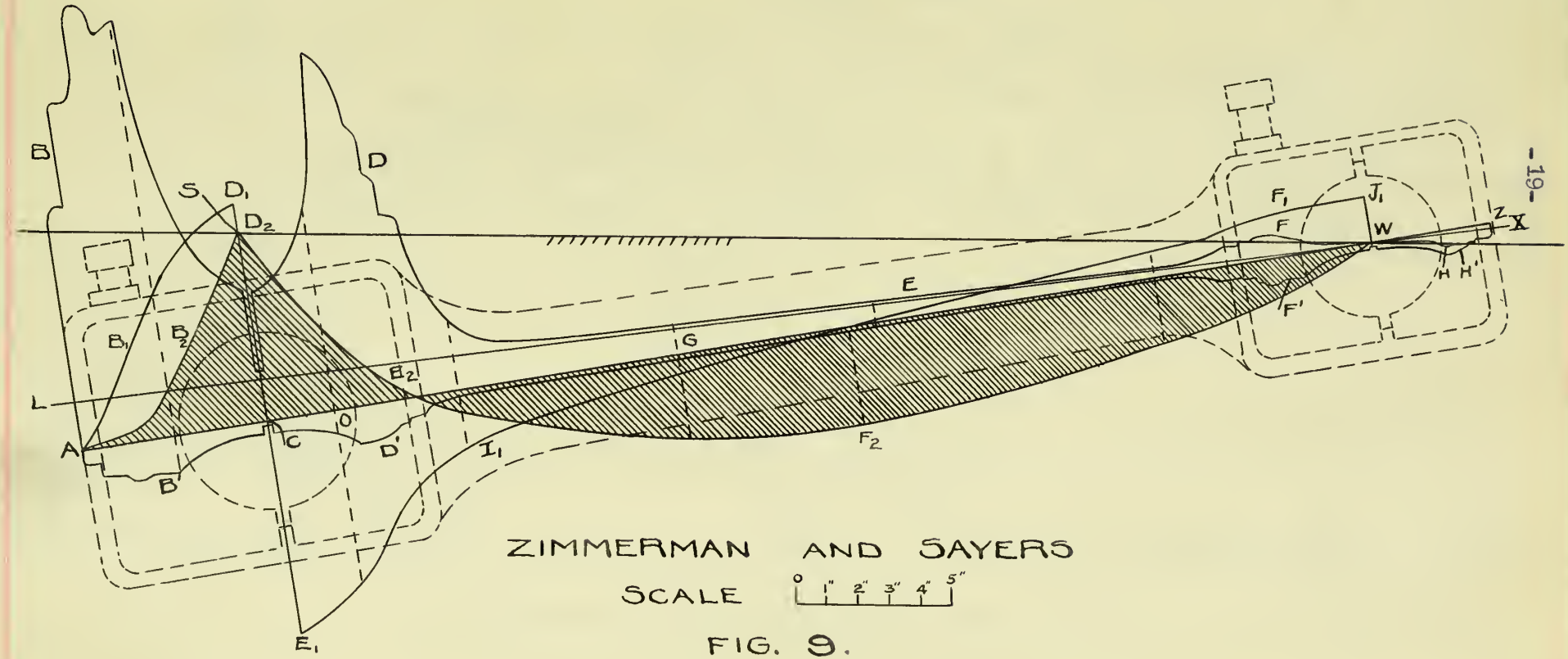
	BRASS		STEEL		
Inches	Volume in cubic in.	Weight, pounds	Volume cubic in.	Weight, pounds	Total Weight
0	0.	0.	0.	0.	0.
	0.	0.	3.97	27.20	27.20
	0.	0.	4.31	40.60	40.60
	0.72	7.42	4.68	43.8	51.20
1	1.37	14.	5.14	48.2	62.20
	5.18	52.6	1.5	14.2	66.80
	5.44	55.3	"	"	69.5
	4.76	48.5	"	"	62.7

ACCELERATION	CURVE	1" =	1480 FT./SEC.^{2}
LOAD	"	1" =	100 POUNDALS
SHEAR	"	1" =	400 "
BENDING MOMENT	"	1" =	3333 INCH POUNDALS



ZIMMERMAN AND SAYERS

SCALE 0 1" 2" 3" 4" 5"

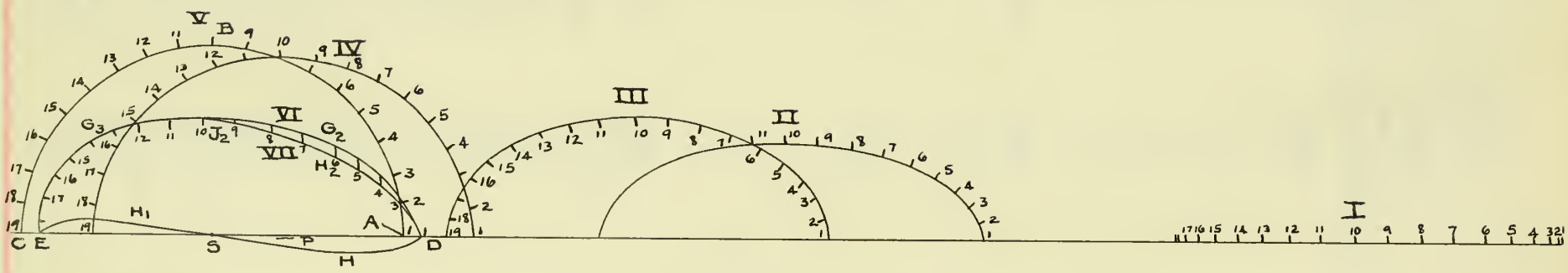
FIG. 9.

I PATH OF CENTER OF WRIST PIN.
II " " " " ROD.
III " " " " GRAVITY.
IV " " " " OSCILLATION.
V " " " " CRANK PIN.
VI POLAR CURVE OF TOTAL INERTIA FORCE.
VII " " " CRANK AND SHAFT REACTIONS.

INTERCEPT ⊥ TO ROD BETWEEN VI AND VII, INERTIA FORCE ALONG ROD.

VERTICAL INTERCEPT BETWEEN VI AND VII, WRIST REACTION.

SCALE OF POLAR CURVES 1"=11709. PDLS. = 364 LB.



ZIMMERMAN AND SAYERS 60 H.P.
SCALE 1"=5"
FIG. 10

	BRASS		STEEL		
Inches	Volume cubic in.	Weight poundals	Volume cubic in.	Weight poundals	Total Weight
2	3.41	34.7	1.5	14.2	44.9
	2.55	25.9	"	"	40.1
	2.01	20.4	"	"	34.6
	1.60	16.3	"	"	30.5
3	1.24	12.6	"	"	26.8
	1.00	10.2	"	"	24.4
	.87	8.85	"	"	23.0
	.79	8.06	"	"	22.2
Wrist	0.	0.	1.46	13.8	14.2
	.79	8.06	1.5	14.2	22.2
	.87	8.85	"	"	23.0
	1.00	10.2	"	"	24.4
5	1.24	12.62	1.5	14.2	26.8
	1.60	16.3	"	"	30.5
	2.01	20.4	"	"	34.6
	2.55	25.9	"	"	40.1
6	3.41	34.7	"	"	44.9
	4.76	48.5	"	"	62.7
	4.38	44.5	1.76	16.5	61.2
	3.41	34.7	2.7	25.35	60.00
7	2.78	28.4	3.93	36.92	65.3
	1.82	18.55	4.8	45.	72.5
	1.4	14.22	5.06	47.5	61.7
	1.4	14.22	5.13	48.2	65.4
8	1.4	14.22	5.06	47.5	61.7
	.7	7.12	4.87	45.7	52.8
			4.5	42.2	42.2
			3.98	37.4	37.4
9			3.28	30.8	30.8
			2.62	24.6	24.6
			2.18	20.23	20.2
			1.84	17.2	17.2
10			1.61	15.26	15.2
			1.46	13.7	13.7
			1.37	12.9	12.9

	BRASS		STEEL		
Inches	Volume cubic in.	Weight poundals	Volume cubic in.	Weight poundals	Total Weight
			1.33	12.5	12.5
11			1.31	12.4	12.4
			"	"	"
			1.32	"	"
			"	"	"
12			"	12.5	12.5
			"	"	"
			1.33	"	"
			"	"	"
13			"	"	"
			"	"	"
			"	"	"
			"	"	"
14			"	"	"
			"	"	"
			"	"	"
			"	"	"
15			"	"	"
			"	"	"
			"	"	"
			1.36	12.6	12.6
16			"	"	"
			"	"	"
			"	"	"
			"	"	"
17			"	"	"
			"	"	"
			1.38	12.6	12.6
			"	"	"
18			"	"	"
			"	"	"
			"	"	"
			"	"	"
19			"	"	"

	BRASS		STEEL		
Inches	Volume cubic in.	Weight poundals	Volume cubic in.	Weight poundals	Total Weight
19			1.38	12.6	12.6
			"	"	"
			1.40	12.7	12.7
20			1.42	12.8	12.8
			"	"	"
			"	"	"
			"	"	"
21			"	"	"
			"	"	"
			1.42	12.8	12.8
			"	"	"
22			"	"	"
			"	"	"
			"	"	"
			"	"	"
23			1.44	12.9	12.9
			"	"	"
			"	"	"
			1.46	13.0	13.0
24			"	"	"
			"	"	"
			"	"	"
			"	"	"
25			"	"	"
			"	"	"
			"	"	"
			"	"	"
26			"	"	"
			"	"	"
			1.47	13.1	13.1
			"	"	"
27			"	"	"
			"	"	"
			"	"	"

	BRASS		STEEL		
Inches	Volume cubic in.	Weight poundals	Volume cubic in.	Weight poundals	Total Weight
27			1.47	18.1	18.1
28			"	"	"
			"	"	"
			"	"	"
			1.48	18.2	18.2
29			"	"	"
			"	"	"
			"	"	"
			"	"	"
30			1.5	"	"
			"	"	"
			"	"	"
			"	"	"
31			"	"	"
			"	"	"
			1.52	18.8	18.8
			"	"	"
32			"	"	"
			"	"	"
			"	"	"
			"	"	"
33			"	"	"
			1.54	18.4	18.4
			1.84	18.5	18.5
			2.07	19.4	19.4
34			2.08	19.5	19.5
			2.31	21.7	21.7
			2.98	28.	28.
			3.51	32.9	32.9
35			4.27	40.	40.
			5.11	50.	50.
	.64	6.59	5.78	54.2	54.9
	1.96	2.14	6.35	59.6	61.7

	BRASS		STEEL		
Inches	Volume cubic in.	Weight poundals	Volume cubic in.	Weight poundals	Total Weight
36	5.58	5.67	4.42	41.5	98.2
	8.65	87.9	2.02	19.05	106.9
	9.01	91.5	1.67	15.7	107.2
	9.38	95.2	1.5	14.2	109.4
37	9.48	95.8	"	"	109.
	8.17	83.	"	"	97.2
	6.	60.9	"	"	75.1
	4.96	50.2	"	"	64.4
38	4.48	45.	"	"	59.2
	3.84	39.	"	"	53.2
	3.38	34.4	"	"	44.6
	3.01	30.5	"	"	44.7
39	2.78	27.7	"	"	41.9
	2.52	25.7	"	"	39.9
	2.37	24.1	"	"	38.3
	2.25	22.9	"	"	37.1
Crank	0.	0.	"	"	14.2
	2.25	22.9	"	"	37.1
	2.37	24.1	"	"	38.3
	2.52	25.7	"	"	39.9
41	2.78	27.7	"	"	41.9
	3.01	30.5	"	"	44.7
	3.38	34.4	"	"	44.6
	3.84	39.	"	"	53.2
42	4.48	45.	"	"	59.2
	4.96	50.2	"	"	64.4
	6.	60.9	"	"	75.1
	8.17	83.	"	"	97.2
43	9.48	95.8	"	"	109.
	8.89	90.1	1.57	14.8	105.8
	7.98	81.2	2.48	23.8	104.
	7.03	71.5	3.91	36.7	108.
44	6.26	63.6	5.13	48.2	111.8

Inches	BRASS Volume cubic in.	BRASS Weight poundals	STEEL Volume cubic in.	STEEL Weight poundals	Total Weight
	5.49	55.8	6.02	56.5	112.3
	4.58	46.5	6.36	59.7	106.2
	3.68	37.4	6.43	60.4	97.8
45	.26	26.4	6.52	61.3	87.7
			6.31	59.2	59.2
			6.1	59.	59.
Total	256.6	2618.21	972.24	8494.27	6112.48
	1	10.117 pdls	1	8.8924 pdls	
	1	.31 lb.	1	.2910 lb.	

b. "The Ideal" Rod.

Figs 11, 12 and 13 are similar to Figs. 8, 9 and 10 and show the results of an investigation on a connecting rod designed for a 50 H.P. "Ideal" high speed steam engine. The leading dimensions are as follows: Cylinder 10 by 10 inches; length of crank, 5 inches; length of rod, 30 inches, speed 300 R.P.M.

The following are the results of the calculations:

W = 52.28 lb.

h = 18.61 inches.

T = 0.826 seconds.

g = 32.17092 ft. per sec.^{2}

k = 12.24 inches.

h_1 = 17.5 "

h_2 = 8.618 "

v = 18.09 ft. per sec.

α_c = 410.685 ft. per sec.^{2}

α_G = 240.632 ft.per sec.^{2}

F_1 = 11966.6 pdls.

F_2 = 1656. "

F = 18622.6 "

R_c = 11378. "

R_s = 11378. "

R_w = 2271. "

Maximum moment = 18648 inch poundals.

s_1 = 10428 odls per sq.in.

= 625 lb. " " "

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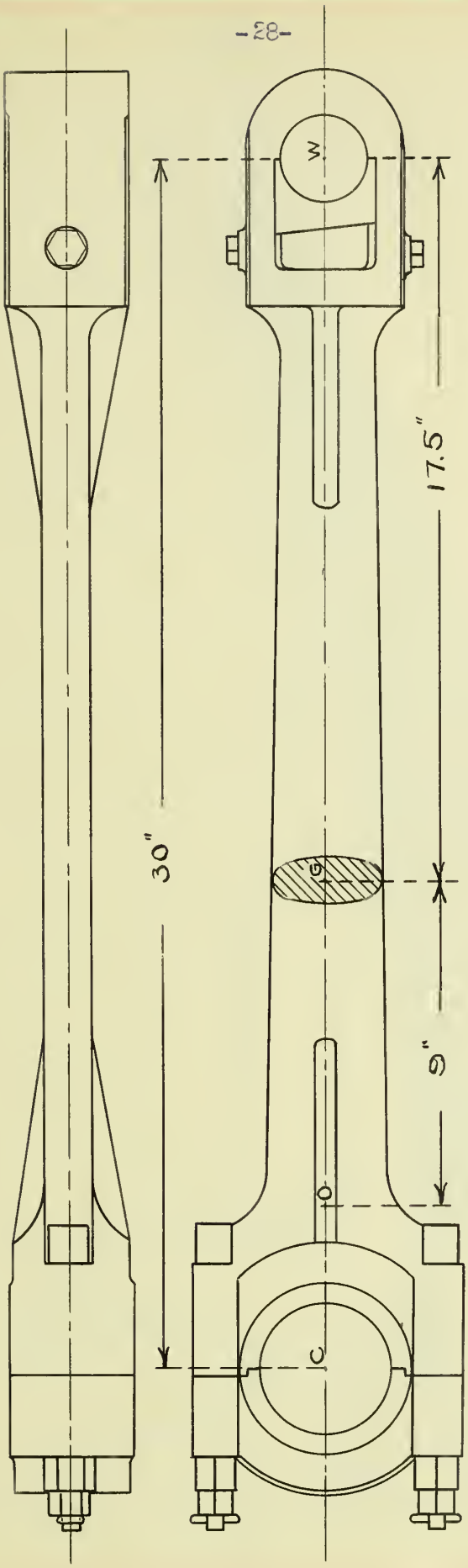
- R E F E R E N C E S -

Klein; Journal of Franklin Institute, Vol.182.

Dalby; "Balancing of Engines."

Dunkerley; Article in London Engineering, June 2, 1899.



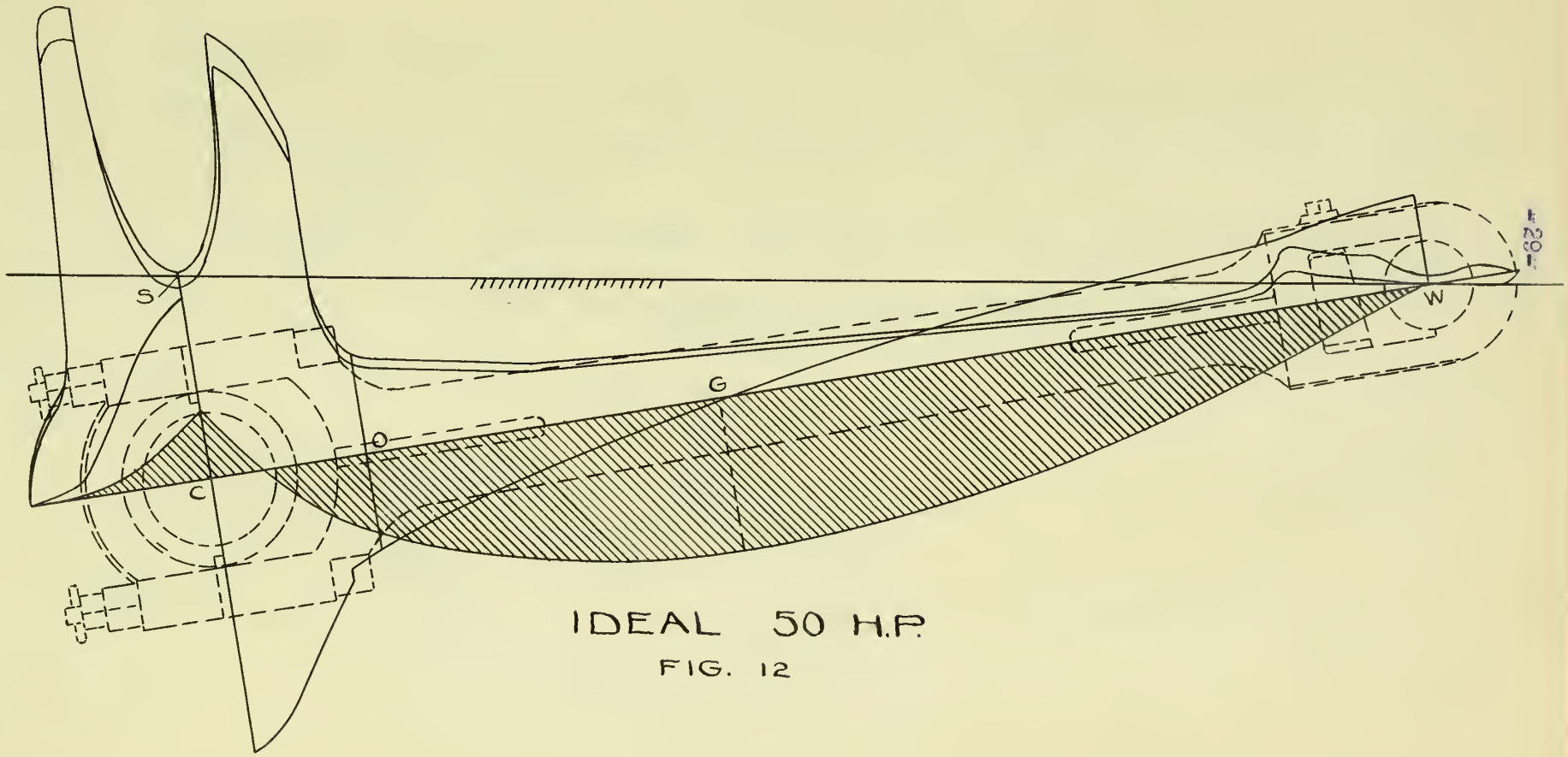
IDEAL 50 H.P.

SCALE 1"=4"

FIG. 11.

SCALE 0 1 2 3 4

LOAD CURVE 1" = 40.85 POUNDALS
SHEAR " 1" = 1000 "
B.M. " 1" = 5000 INCH POUNDALS



IDEAL 50 H.P.

FIG. 12

I PATH OF CENTER OF WRIST PIN.

II " " " " ROD.

III " " " " GRAVITY.

IV " " " " OSCILLATION.

V " " " " CRANK PIN.

VI POLAR CURVE OF TOTAL INERTIA FORCE.

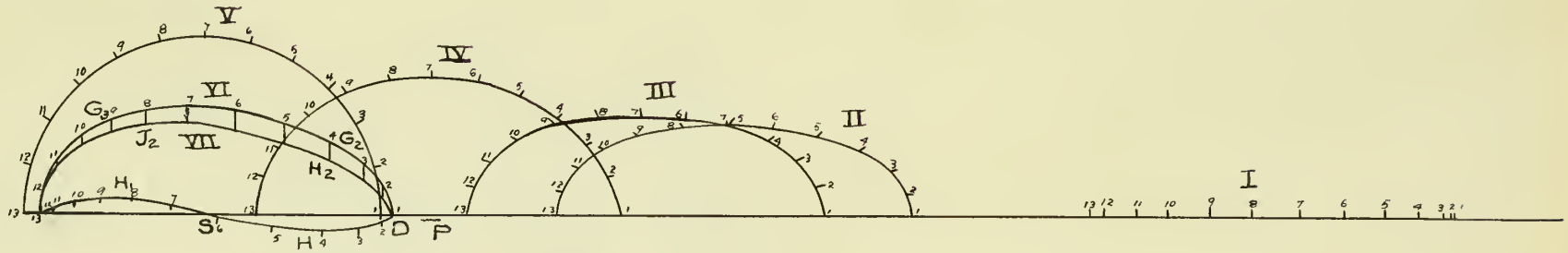
VII " " " CRANK AND SHAFT REACTIONS.

INTERCEPT ⊥ TO ROD BETWEEN VI AND VII, INERTIA FORCE ALONG ROD.

VERTICAL INTERCEPT BETWEEN VI AND VII, WRIST REACTION.

SCALE OF POLAR CURVES 1" = 409 PDLS. = 364 LB.

" " DRAWING 1" = 5"



IDEAL 50 H.P.

FIG. 13

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